APPENDIX A

Stability Evaluation of Little Tunnel, Cumberland Gap, Tennessee.

Report by Golder Associates, May 1986.

Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

REPORT ON

STABILITY EVALUATION OF LITTLE TUNNEL
CUMBERLAND GAP, TENNESSEE

Prepared for:

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May 1986

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Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

May 23, 1986 853-3256

Federal Highway Administration
Cumberland Gap Project
P.O. Box 15
Harrogate, TN 37752

Attn: James R. Campbell

Enclosed please find a copy of our report on Little Tunnel. Revisions have been made to the draft report incorporating your's and Lee Wan's comments.

We appreciate the opportunity to work with you on this project and any further work in which we can be of assistance. If you have any questions, please contact us.

Very truly yours,

GOLDER ASSOCIATES

W. Randall Sullivan, P.E.
Associate

Richard W. Humphries, P.Eng.
Associate

WRS/RWH:cee

Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

May 23, 1986 853-3256

Lee Wan & Associates
4321 Memorial Dr., Suite P
Decatur, GA 30032

Attention: Mr. Michael Stieferman, P.E.

RE: RELOCATION OF U.S. 25E
CUMBERLAND GAP, TENNESSEE

Gentlemen:

Enclosed please find a copy of our revised report on Little Tunnel. Revisions have been made as per your comments and one additional solution has been included which has changed the recommendations. To avoid reproducing additional copies of the photographic record, will you please substitute these pages of the text and the title pages for those in the original draft copy that was sent you on March 7, 1986.

We appreciate the opportunity to assist you on this project and we look forward to working with you on the design of the remediation. If you have any questions, please contact us.

We are sending copies of this final report directly to FHWA as discussed previously.

Very truly yours,

GOLDER ASSOCIATES

W. Randall Sullivan, P.E.
Associate

Richard W. Humphries, P.E.
Associate

WRS/RWH:cee

Enclosure

EXECUTIVE SUMMARY

Little Tunnel is a 1000-ft. long single-track railroad tunnel built in the 1890's. The eastern 758 ft. of the tunnel is supported by a system of timber sets and lagging. The remaining 276 ft. is supported by a brick lining.

The brick-lined section is in excellent condition. It is expected to carry the additional load imposed by the planned highway embankments with a wide margin of safety.

Most of the timber and lagging have surface deterioration, but are still capable of carrying substantial loads. In a small percentage of the tunnel, the lagging has deteriorated severely or is absent entirely.

Serious stability problems exist at three locations in the tunnel. The locations of these, the nature of the problem, and the recommended remedial measures are as follows:

1. <u>Bays 183 through 187</u>: Timbers in the left haunch are distorted and sets severely deteriorated. The planned U.S. 58 embankment crosses the tunnel at this location. Thus, remedial work should be completed before the embankment is constructed.

   The recommended remedial work involves constructing a reinforced concrete liner immediately below the existing lagging, conforming to the shape of the existing timber set and lagging system.

2. <u>Set 105-106</u>: Here the crown member has displaced downward under load and is not in full contact with the right haunch member.

It is recommended that the set be repaired by bolting a new timber crown piece to the existing one and to the haunches.

3. East portal through Bay 12: Timbers in the right haunch are distorted from Bays 8 through 12 and corresponding ground subsidence can be seen at the surface above Bays 8 through 12. Ground subsidence can also be seen between Bay 8 and the portal.

   The recommended remedial work involves constructing a reinforced concrete liner, similar to Bays 183 through 187. In addition, suspected large existing voids above the tunnel crown should be filled by pumping in a sand slurry from ground surface, following completion of the reinforced concrete work. Finally the ground above the east portal section will be graded and the existing subsidence depressions filled in.

It is recommended that vibration monitoring be carried out in Little Tunnel during the nearby excavation for U.S. 25E and that the peak particle velocity be limited to 2 in. per sec.

TABLE OF CONTENTS

1.0 INTRODUCTION

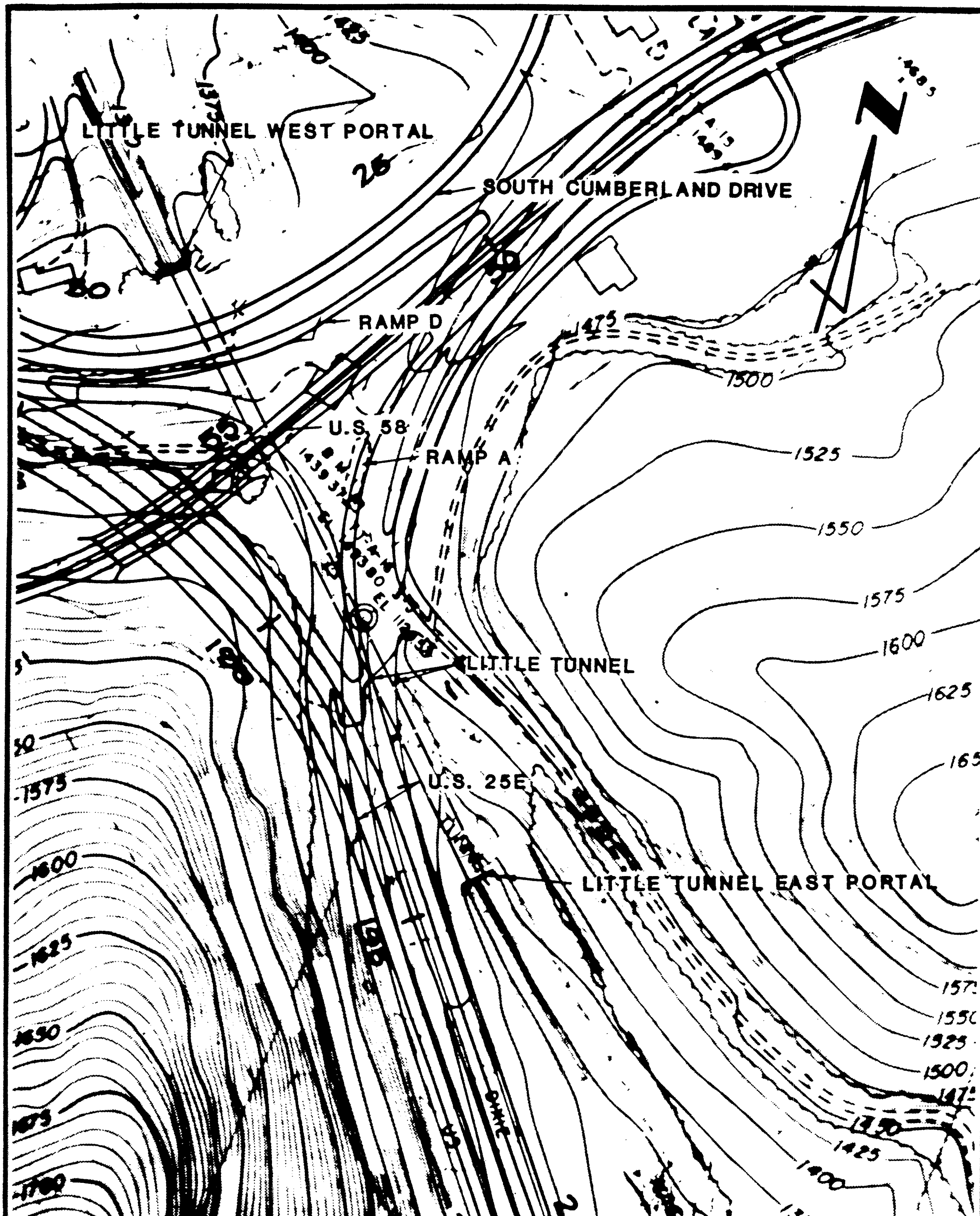
Little Tunnel is a single-track, 1000 ft. long railroad tunnel located between Cumberland Gap and Harrogate, Tennessee. It was constructed in the 1890's.

The Federal Highway Administration (FHWA) is serving as the project manager for the National Park Service on the relocation of U.S. 25E between Cumberland Gap, Tennessee and Middlesboro, Kentucky. A part of the highway relocation involves embankment construction above Little Tunnel.

A current proposal calls for possibly using Little Tunnel as a utility corridor. Under these plans, the tunnel would house water and sewer lines and a high voltage electrical transmission line.

Design work for the part of the highway relocation in Tennessee (and a very small section in Virginia) is being carried out by Lee Wan and Associates of Atlanta, Georgia. In 1984, Golder Associates, acting as sub-consultants to Lee Wan & Associates, conducted a field investigation and provided geotechnical design recommendations for surface construction on the project. The report on that work was dated June 21, 1984. It was agreed in 1984 that Golder Associates' detailed survey of conditions in Little Tunnel would be delayed until construction began on the pilot tunnel through Cumberland Mountain.

The location of Little Tunnel in reference to the highway relocation work is shown in Figure 1. The present owner of the tunnel is the Seaboard System Railroad, Inc. The line and the tunnel have been essentially abandoned for a number of years and recently Seaboard has applied to officially abandon them. We understand that, upon abandonment by the railroad, the ownership of the tunnel reverts back to



JOB NO. 853-3256	SCALE 1" — 200'	SITE PLAN – LITTLE TUNNEL
DRAWN JLW	DATE 2-18-86	
CHECKED	DWG. NO.	
Golder Associates	LEE WAN & ASSOCIATES	FIGURE 1

the original land owners or their successors--in this case, with right-of-way acquisition for the highway relocation, the National Park Service would ultimately become the owners of Little Tunnel.

Golder Associates' scope of work on Little Tunnel is as follows:

1. Carry out a condition survey of the existing brick and timber supports,
2. Develop a photographic record of the tunnel supports,
3. Install convergence points at representative and critical locations for monitoring support behavior during highway construction,
4. Evaluate the effect of proposed highway construction on the stability of the tunnel,
5. Recommend remedial measures needed to make the tunnel suitable for use as a utility corridor.

This report provides the results of the condition survey, an evaluation of tunnel stability, and recommendations for remedial measures. The sketches given in this report are conceptual. Detailed designs and specifications for construction are to be included in the design package submitted at a later date.

2.0 CONDITION SURVEY

2.1 General

The condition survey of Little Tunnel was carried out between January 21 and January 31, 1986. A 28 ft. extension ladder was used to reach the crown and haunch. A portable generator and lights provided the necessary lighting.

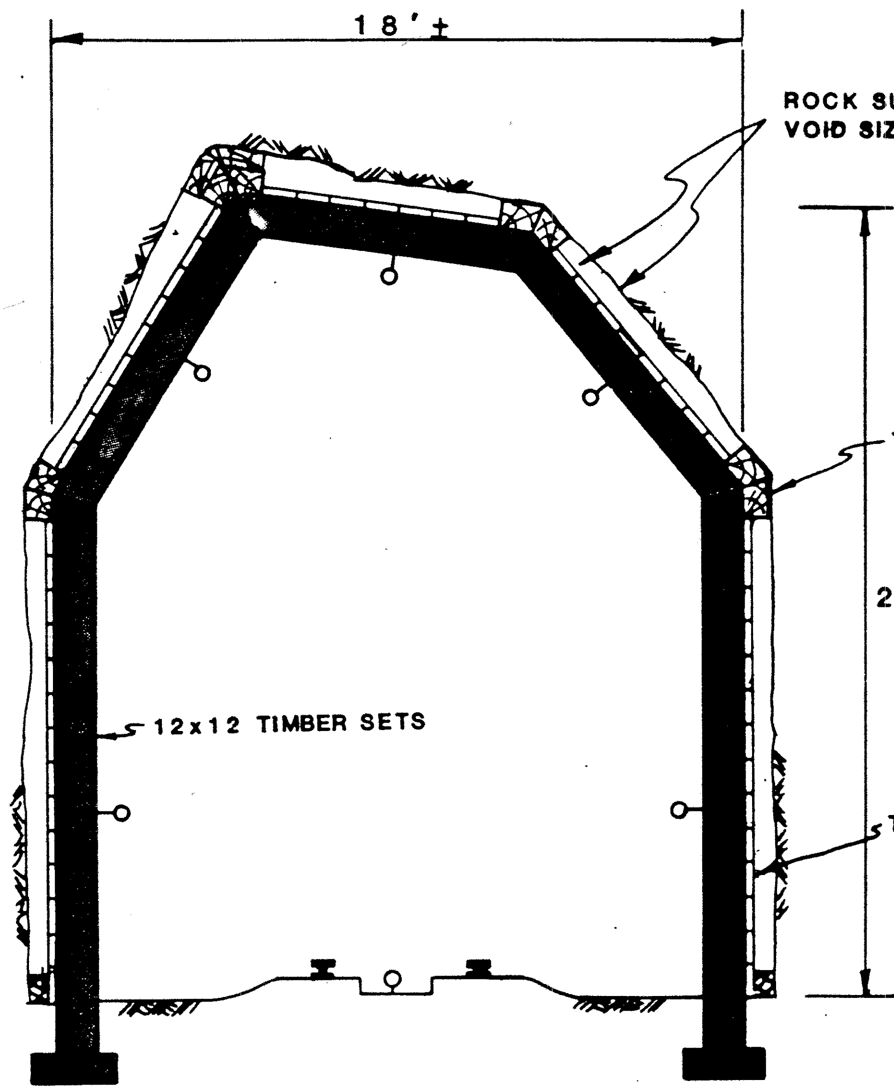
The survey began at the east portal. The outside of the first timber set was arbitrarily designated as Station 10+00. The bays between timber sets were numbered sequentially beginning with "1" at the east portal. Individual sets were identified by the bay number on each side.

The tunnel is supported by timbers from the east portal to a distance of 758 ft. from the east portal. The remaining 276 ft. is supported by a brick lining.

2.2 Timber Section

The timber support consists of 12 in. X 12 in. timber sets placed at 4 ft. on centers and 3 in. X 9 in. timber lagging. A typical cross section of a timber sets is provided in Figure 2. The practice of the day was to block the sets to the rock at the miter joints using timber cribbing. For safety reasons, we were able to actually observe the cribbing at only a few locations where it could be seen through openings in the lagging. Thus, the actual locations and conditions of the cribbing remain unknown.

The rock was observed to be tight against the lagging in some places, while voids up to 4 ft. deep were seen in other places. Typically, the void between the lagging and the rock was larger above the haunches and crown than behind the walls.



NOTE:

1. LENGTHS OF SET MEMBERS, HAUNCH AND CROWN ANGLES VARY.
2. BLOCKING TO ROCK MAY VARY FROM THAT SHOWN.

LEGEND

—o EYEBOLTS FOR CONVERGENCE MONITORING LOCATED AT STA. 17+25.6 and 17+53.6.

JOB NO. 853-3256	SCALE 1" = 5'	TYPICAL TIMBER SUPPORTED SECTION
DRAWN SKB	DATE 2-14-86	
CHECKED	DWG. NO.	
Golder Associates		LEE WAN & ASSOCIATES — FIGURE 2

The condition of the timber sets and lagging is depicted in Figure 3. Figure 3 is a plan view of the tunnel with the haunches and sides folded up to a horizontal plane. Only conditions that appeared to deviate substantially from the typical condition are shown in Figure 3. It should be noted that the conditions shown in Figure 3 are based largely on visual observation. A physical examination was conducted at representative locations throughout the tunnel length. A detailed physical examination of each timber was beyond the scope of the investigation.

Typically, the timber sets and lagging are rotted on the surface but otherwise appear to be sound and capable of carrying near their original capacity. Localized splitting of the timber sets was frequently observed. The splits usually extend an inch or less into the sets and do not appear to appreciably affect their load carrying ability. Where an intermediate level of deterioration is shown in Figure 3, the set's load carrying capacity was judged to be reduced but is still substantial. Where severe deterioration is indicated, the timber is considered to retain a minimal load carrying capacity and additional support is required.

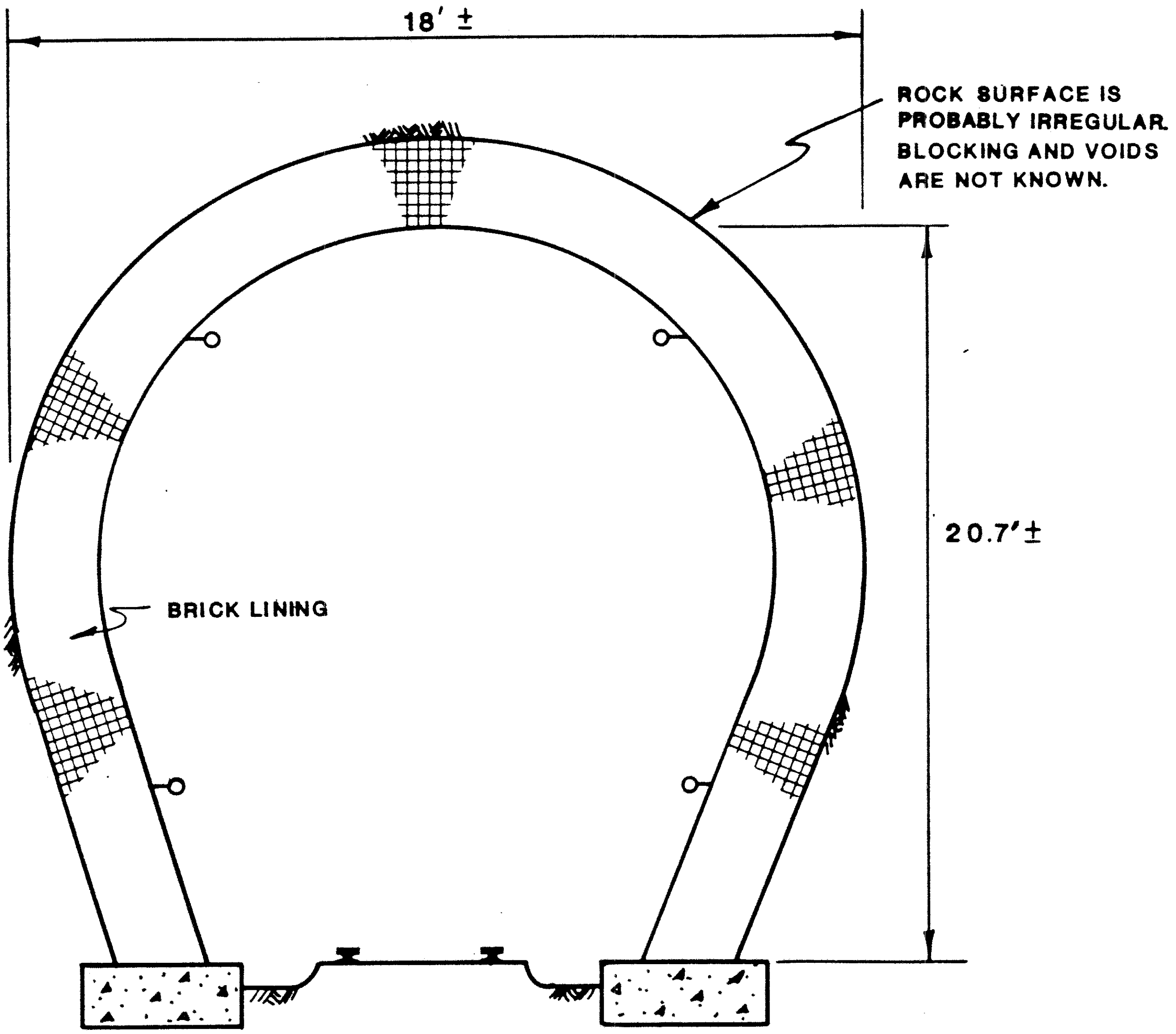
A complete photographic record of the timber supports is provided in Appendix A. Three bays are included in each set of photos. A set contains five photos: one of each wall, one of each haunch, and one in the crown. Each photo shows the number of the middle bay and an "L" and an "R" which indicate left (south) or right (north) walls respectively. The photos are arranged in Appendix A with a set of five on each sheet.

2.3 Brick Section

The brick lining is horseshoe shaped, with sides that curve inward, as shown in Figure 4. The thickness of the lining and the contact it makes with the rock can be seen only at the end of the brick lining inside the tunnel. There it has a minimum thickness of 2.1 ft. and is thicker where it was necessary to fill in irregularities in the rock. Timber cribbing is also visible in the larger irregularities. The overall width and height of the brick lining is about the same as the timber supports. This suggests that any timber sets placed during original tunnel excavation were removed as the brick lining was erected.

The brick lining is in excellent condition. Both bricks and mortar remain hard. No cracks larger than hairline in width were observed, and no active seepage was observed. There was evidence of slight seepage in the form of a light colored precipitate on the brick in some areas. The crack-free condition of the brick also suggests that the lining was built tightly against the rock. If it had not been, rock loading would almost certainly have induced moments in the brick lining at some locations and caused it to crack.

It was agreed with FHWA during the field inspection that photos covering the entire brick lining would not be necessary, given its excellent condition. Photos taken at two typical stations are provided in Appendix A. The two stations selected were those where convergence points were installed. These locations also correspond approximately to the locations where highway embankments will be built above the brick lined section.



NOTE:

1. SHAPE OF ROCK SURFACE BEHIND BRICK IS UNKNOWN.

LEGEND

—o EYEBOLTS FOR CONVERGENCE MONITORING LOCATED AT STA. 18-75 and 19-7.0.

JOB NO. 853-3256	SCALE N.T.S.	TYPICAL BRICK SUPPORTED SECTION
DRAWN SKB	DATE 2-14-86	
CHECKED	DWG. NO.	
Golder Associates		LEE WAN & ASSOCIATES — FIGURE 4

2.4 Portals

Photos of the portals are provided at the beginning of Appendix A. The west portal headwall appears to be in satisfactory condition. There is no evidence of any surface subsidence or slope instability at the west portal.

At the east portal there are major stability problems. We observed two large subsidence pits centered at about 16 ft. and 36 ft. behind the headwall and another small subsidence immediately behind the headwall (see Figure 9). The subsidence pit at 36 ft. behind the headwall corresponds to the bulge in the timber supports within the tunnel from Bay 8 through 12.

2.5 Convergence Points

Sets of convergence points, consisting of galvanized steel eye bolts, were installed at four locations. Two sets were installed in timber sections and two sets in the brick lining. Those in the timber section are located approximately where the embankment for U.S. 58 will cross the tunnel. The two brick sections were located approximately where the Ramp D and South Cumberland Drive embankments will cross the tunnel.

The locations of convergence points on the timber and brick cross-sections are shown in Figures 2 and 4 respectively. Points were marked in the field with red spray paint. Station locations of the instrumented cross-section are as follows:

NO.	SUPPORT	STATION
1	Timber	17+25.6
2	Timber	17+53.6
3	Brick	18+75
4	Brick	19+70

An estimate of the acceptable movements in the tunnel during embankment construction can be made by estimating the elastic compression of the supports due to the embankment load. To do this, certain assumptions must be made concerning the distribution of the added load with depth and the stiffness of the supports.

Elastic theory suggests the vertical stress increase in the crown of the tunnel due to the additional load from the new embankment crossing a short section of the tunnel is about 50 percent of maximum stress applied by the embankment at the ground surface. The maximum height of the embankment crossing the tunnel is 16 ft. above existing ground level, and the corresponding increase in vertical stress at tunnel crown level due to the embankment is estimated at 1200 psf.

In the case of the timber supported section beneath the 16 ft. high U.S. 58 embankment, the rock is many times stiffer than the flexible timber support system and the additional load is expected to be carried fully by the stiffer tunnel wall rock. Thus, convergence at monitoring stations in the timber sets are expected to be less than the measuring accuracy of the tape extensometer: (0.005 in.).

In the case of the brick lined section, the stiffness of the support is much greater than with timbers. Thus, the brick lining is expected to take much of the 1200 psf of additional load. However, the stiffness of this 2 ft. thick lining is so large that the resulting elastic movement is estimated to be less than the measuring accuracy of the tape extensometer (0.005 in.).

It is anticipated that the convergence at the four instrumented locations will be less than the 0.005 in. measuring accuracy of the tape extensometer. Thus, if any measurable, systematic convergence is observed, it will probably be a result of inelastic behavior, i.e. dislodging of blocks by vibration or the re-distribution of loads around the opening. In the event of measurable movements, Golder Associates should be contacted and the cause of the movement should be investigated before additional fill is placed over the tunnel.